TECHNICAL REPORT 93-021

NIGHT VISION CAMCORDER SYSTEM

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In order to obtain night vision device imagery, a portable lightweight night vision camcorder system has been designed. This system has the capability to record night vision imagery in confined quarters (e.g., cockpits) and other remote sites under various environmental conditions. The system is composed of a commercial third generation night vision monocular, a special optical coupler, and a consumer camcorder. Engineering drawings for the optical coupler are included as an appendix. Laboratory experiments were performed to determine the night vision camcorder system imaging characteristics. The results of these experiments indicate that the limiting resolution of recorded night vision video is about 30% to 40% of the limiting resolution of the third generation monocular, depending upon the type of video filming method used.

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EXECUTIVE SUMMARY

Introduction

One of the current research objectives of the Simulation of Advanced Sensors project is to obtain quantifiable night vision device imagery under diverse nighttime environments (e.g., time of night, moon angle/phase, clouds, fog, sea state, lights, flares). To obtain the preliminary visual data to meet this objective, a portable lightweight night vision camcorder system was designed, composed of a commercial night vision monocular, a special optical coupler, and a consumer camcorder. The purpose of this report is to document this system and provide information concerning its imaging characteristics.

Night Vision Camcorder System

The night vision camcorder system consists of a commercially available third generation night vision monocular and a consumer model Hi8 format camcorder that have been optically and mechanically coupled via a special in-house designed mounting mechanism. This system has the capability to record night vision imagery in confined quarters (e.g., cockpits) and other remote sites under various environmental conditions.

System Resolution Tests

To determine the imaging characteristics of the night vision camcorder, laboratory tests were performed. Under identical optimal viewing conditions, we found the limiting resolution of the recorded Hi8 format night vision video for both full and part field was about 11% less than that of the live night vision video. The limiting resolution of recorded night vision video is about 30% to 40% of the limiting resolution of the third generation monocular, depending upon the type of video filming method used.

Conclusions

Laboratory tests showed that under ideal conditions, the best resolution that can be obtained by the night vision camcorder system was about .321 line pairs per milliradian. Two video filming methods were investigated. When using the night vision camcorder system, either full field or part field video recording methods may be used, depending upon the particular circumstances. Under some situations, the ability to capture increased resolution video may be more important than capturing the full field of view of the night vision device.

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INTRODUCTION

The expansion of Navy and Marine Corps roles into littoral night operations has increased the use of night vision goggles (NVGs) in low-altitude flight missions and certain areas of shipboard operation. Third generation or "Gen 3" NVGs such as the Aviator's Night Vision Imaging System (ANVIS), allow tasks to be performed even under starlight only conditions. However, from night-to-night and hour-to-hour, the appearance of targets and terrain can change significantly. Safe effective use of night vision equipment such as ANVIS requires operators to be aware of and trained to recognize night illumination characteristics, as well as understand and respect current equipment capabilities and limitations.

One of the current research objectives of the Simulation of Advanced Sensors project is to obtain quantifiable NVG imagery under diverse nighttime environments (e.g., time of night, moon angle/phase, clouds, fog, sea state, lights, flares). To obtain the preliminary visual data to meet this objective, a portable lightweight night vision camcorder system was designed, composed of a night vision monocular, a special optical coupler, and a consumer camcorder. The purpose of this report is to document this system and provide information concerning its imaging characteristics.

NIGHT VISION CAMCORDER SYSTEM

The system consists of a commercial Gen 3 night vision monocular with a 27 millimeter (mm) "minus blue" objective lens, and a Hi8 format consumer camcorder that have been optically and mechanically coupled via a special in-house designed mounting mechanism. This system has the capability to record Gen 3 night vision imagery in confined quarters (e.g., cockpits) and other remote sites under various environmental conditions. The system is light and easy to use. An optional aluminum mounting plate allows standard ¼-20 threaded tripods and other optical mounts to be used. Figure 1 shows the assembled system. See Appendix A and B for engineering notes and drawings.

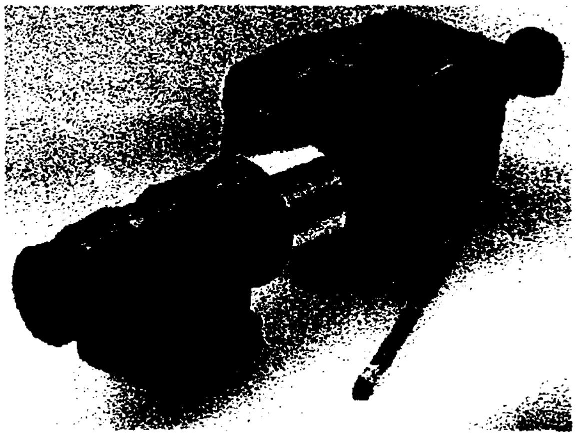

Fig 1. Monocular, Optical Coupler & Camcorder

Night Vision Monocular

A Litton M944 module with an ANVIS-type Gen 3 image intensifier assembly is used as the night vision monocular. When used with an ANVIS-type 27 mm focal length objective lens having a minus blue coating, the magnification, field of view, brightness gain, and system resolution are essentially equivalent to that of the ANVIS. It weighs about 1.5 lbs, and accepts a military standard AN/PVS NVG 27 mm focal length eyepiece lens. It uses a single "AA" alkaline battery as a power source.

Camcorder

The recording device used is a commercial Sony Hi8 Camcorder, model CCD-TR101. It weighs about 1.9 lbs and has auto/manual controls for focus, white balance, shutter speed, and exposure. It has a 10x zoom lens whose focal length varies between 6.2 and 62 mm. An intriguing, but as yet unused (by us) feature of the camcorder is its ability to perform optical image stabilization. According to manufacturer literature, the charge coupled device (CCD) imaging chip that is used in the camcorder contains 410,000 pixels. Although the measurement conditions are not specified, the literature also states that the horizontal system resolution is more than 400 TV lines and the minimum illumination level is 3 lux.

Optical Coupler

To connect the monocular and camcorder together, both mechanically and optically, we designed a coupler. This coupler mechanically keeps the camera lens and monocular image coaxial and optically increases the macro focusing range. Figure 2 shows the disassembled coupling mechanism. One end of the black plastic barrel screws into the rear of the monocular, while the other end slides into an aluminum housing. The aluminum housing consists of two tubular pieces that screw together to secure the lens. This whole assembly then screws into the 52 mm objective filter mount on the camcorder. Complete engineering drawings for the optical coupling system as tested are contained in Appendix B. Note that two different lens elements are discussed in Appendix A. The tested coupling mechanism was not an optimal solution. Time and logistical constraints led to the use of an uncoated equi-convex lens element in the coupler. A plano-convex lens would be the "best form" singlet shape for the conjugate ratio involved; with the plano side toward the monocular output image (Meyer-Arendt, 1972, pp. 112-117). An achromat would perform even better than a plano-convex lens. Use of an achromat is suggested, although the extent of the system resolution improvement is not known.

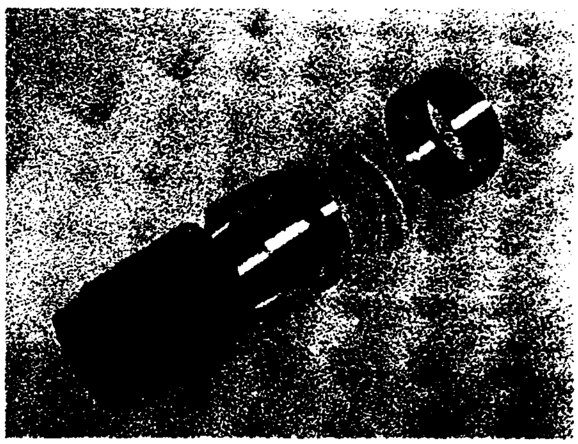

Fig 2. Optical Coupling System

SYSTEM RESOLUTION TESTS

Although the limiting resolution of the night vision monocular is specified to be greater than .76 line pairs per milliradian (lp/mrad) and the horizontal resolution of the camcorder is stated to be greater than 400 television lines, the resultant resolution after coupling the two systems together was unknown. To better document the limiting resolution of the assembled monocular, coupling mechanism, and camcorder, laboratory measurements were performed. We first tested the monocular and the camera separately. Then, the two were tested as a system using the in-house designed coupler.

During portions of the test involving the camcorder, live video was directly output from the camcorder via an S-video connector to a Sony Triniton Superfine Pitch monitor, model number PVM-1344Q. Manufacturer literature available on this model stated that its horizontal resolution was better than 600 TV lines. This allowed us to view the resultant video on a high resolution color monitor and adjust for best video output.

Note that subjective video resolution tests have historically been performed using a black and white high resolution monitor. We used this color monitor due to a lack of access to a high resolution black and white monitor. It is possible that the test results would have shown slightly higher observable resolution if a suitable black and white monitor had been used.

To evaluate the resultant recorded video, a consumer quality Sony model EV-S3000 Hi8 VCR was used for playback. The video was output via an S-video connector to the same color monitor used to view the live video output. Sony Hi8 Metal P brand video tape was used as the recording medium. A more comprehensive test using other brands/models of VCRs and video tapes probably would have altered the results, but was beyond the scope of our original investigation.

Camcorder Tests

As a first step, the resolution of the camcorder was tested to subjectively find its limiting horizontal and vertical resolution. An appropriately lighted video resolution chart having a series of converging vertical and horizontal lines was placed approximately 1 meter away from the camcorder. The camera focus was then manually adjusted for optimum resolution and the camera lens zoomed to allow the resolution chart to fill the video frame. White balance, shutter speed, and exposure controls were left on automatic and the optical stabilization feature was turned off. Horizontal and vertical resolution were determined by examining the live video on the monitor and subjectively observing the point at which the converging lines became indistinct. From these tests, we found that the horizontal resolution was about 500 lines and the vertical resolution was about 400 lines.

The next step was to playback the above camcorder resolution tests to observe the effect of the recording/playback process. As expected the resultant recorded video resolution was not as good. Upon playback we could still resolve 400 lines vertically but the horizontal resolution had dropped to about 400 lines.

Due to the continuous nature of the resolution wedges on the test chart, exact readings were not possible. Also, since we relied on the factory camcorder calibration, it is possible that the resolution test results could have been improved by internal camcorder adjustments that were not available to us.

Monocular Tests

We closely followed MIL-A-49425, Military Specification for Aviator's Night Vision Imaging System, paragraph 4.6.4 in arranging the laboratory setup for Gen 3 monocular resolution measurement. A positive, 100 percent contrast, USAF 1951 resolving power test target was placed in the infinity focal plane of a test collimator with an effective focal length (EFL) of 908.45 mm (see Figure 3). Target brightness and monocular objective focus were adjusted for maximum monocular on-axis resolution by viewing the target elements through the monocular eyepiece. If three horizontal and three vertical bars of the element were discernible by both subjects, the element was judged resolved.

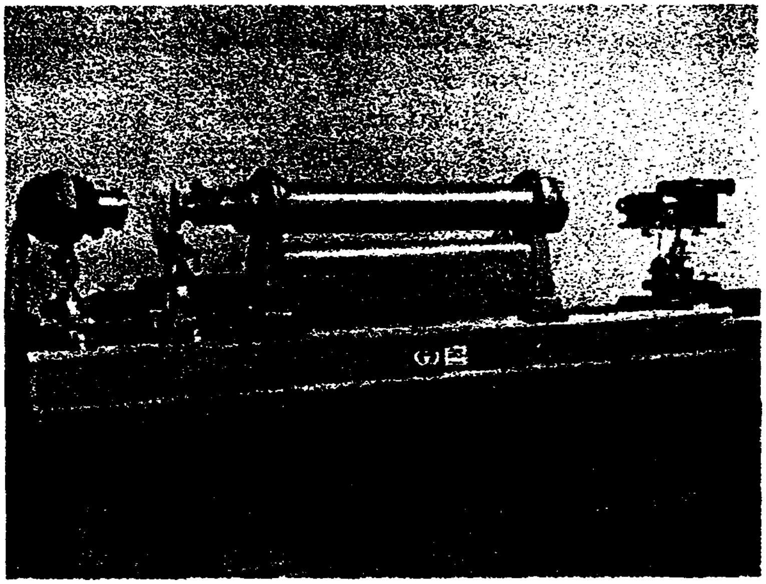

Fig 3. Resolution Measurement Setup

After the initial adjustments were made, Group -1, Element 5 was judged resolved and Element 6 was judged just barely resolvable by both subjects. To calculate the system resolution of the monocular, the equation provided in MIL-A-49425, paragraph 4.6.4 was used. This equation calculates the system resolution, R, in cycles per milliradian (or equivalently line pairs per milliradian, lp/mrad) according to:

$$R = RA\ (\text{Collimator EFL}) \ / \ 1000$$

where RA is the USAF 1951 group/element cycles per millimeter (or equivalently line pairs per millimeter). Substituting we found:

Group -1, Element 5: .7937 (908.45) /1000 = .721 lp/mrad
Group -1, Element 6: .8909 (908.45) /1000 = .809 lp/mrad

From this data we found that the limiting resolution of this monocular was about .81 lp/mrad.

Combined System Tests

Having adjusted the monocular objective focus and target brightness for optimum resolution, we next removed the monocular eyepiece and replaced it with our optical coupling mechanism and camcorder. The camcorder was then manually adjusted for best focus by observing the live video output on the same monitor that had been previously used to measure the camera response. To avoid stray illumination on the resolution target, the monitor was enclosed by a box and the monitor screen viewed through a small opening. Monitor controls were also readjusted for best test target contrast. During the data collection, the camcorder recorded both the test target video and comments concerning the appearance of the test targets.

To achieve a meaningful result, two zoomed positions were chosen as representative of the current methods of shooting NVG video. The first method fills the video frame with the circular NVG field of view (FOV) vertically. This allows the full NVG FOV to be viewed on the resulting video. The second method fills the video frame horizontally with the circular NVG image. This reduces the FOV vertically (cuts off the top and bottom of the NVG FOV) but enables the video to be collected at a higher resolution. These two methods are referred to as full field and part field, respectively.

In the full field method, while viewing the live video, we could resolve Group -2, Element 3, but not Group -2, Element 4. This corresponded to a limiting system resolution of:

Group -2, Element 3: .315 (908.45) /1000 = .286 lp/mrad

While viewing the recorded video, we could resolve Group -2, Element 2, but not Group -2, Element 3. This corresponded to a limiting system resolution of:

Group -2, Element 2: .280 (908.45) /1000 = .254 lp/mrad

In the part field method, while viewing the live video, we could fully resolve Group -2, Element 5, but only the vertical elements of Group -2, Element 6 could be resolved. This corresponded to a limiting system resolution of:

Group -2, Element 5: .397 (908.45) /1000 = .361 lp/mrad

While viewing the recorded video, we could fully resolve Group -2, Element 4, but not Group -2, Element 5. This corresponded to a limiting system resolution of:

Group -2, Element 4: .354 (908.45) /1000 = .321 lp/mrad

Under identical optimal viewing conditions, we found the limiting resolution of the recorded Hi8 format night vision video for both full and part field was about 11% less than that of the live night vision video. The limiting resolution of the recorded night vision video was about 30% to 40% of the limiting resolution of the Gen 3 monocular depending upon whether we used the full field or part field video filming method. Our investigation clearly showed that the best resolution that can be obtained by our system was about .321 lp/mrad. These findings are conservative since a discrete target set was used for our resolution measurements. In most instances the actual limiting resolution lies somewhere between that of the resolved element and the unresolved element.

CONCLUSIONS

To obtain preliminary night vision imagery we developed a light weight night vision camcorder system composed of commercially available components and a specially designed optical coupler. To determine some of its optical characteristics laboratory tests were performed. Under ideal conditions, our investigation indicates that the best resolution that can be obtained by our night vision camcorder system is about .321 lp/mrad. Use of an achromat lens in the optical coupler should improve the system resolution.

We desire better resolution, however, we recognize that there are inherent tradeoffs between small portable consumer video systems and larger professional video systems that may be acceptable. There are also tradeoffs in the video medium itself. When using the night vision camcorder system described above, either full field or part field video techniques may be useful, depending upon the particular circumstances. Under some situations, the ability to capture increased resolution video may be more important than capturing the full FOV of the night vision device.

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APPENDIX A

Notes On The Optical Coupler Engineering Drawings

The use of an optical element in this coupler was brought about by the need to fill the field of view (FOV) of the camcorder. Filling the FOV would allow the monocular image to fill the video raster and maximize the resolution of the image. Upon attempting to use the camcorder in macro mode to view the monocular image, we found that the monocular housing prevented the camcorder lens from being positioned close enough to fill the FOV. Adjustment of the camcorder zoom to reduce the FOV from wide-angle toward a more telephoto setting (to fill the video raster) would not work either, since that adjustment took the lens out of macro mode and focus could not be maintained. By adding a positive lens element in front of the camcorder lens, we extended the macro range to a higher zoom setting and thus filled the video raster with the monocular image.

The recommended lens element for use with this optical coupler is a coated achromat lens. The diameter should be 50 mm and the focal length between 50 - 100 mm. Experimental tests of lenses with focal lengths in this range suggested that a focal length of about 75 mm was optimum. Shorter focal lengths allowed a higher magnification, but resulted in more image distortion. During our tests, tne focal length and object relationship result in the formation of an erect virtual image that is magnified six times and is positioned -381 mm from the lens. This image is viewed by the camcorder lens system with its zoom set just beyond the macro position and focus set to infinity. Note that an achromat is NOT the lens that was used in the system tested in this report. The lens used for the tests described in this report was an uncoated, 50 mm diameter equi-convex singlet lens with a 76.2 mm focal length. It was used because it was the correct focal length and diameter and was immediately available for testing. An anti-reflection coated achromat lens is a better choice because it would reduce image aberrations (spherical, chromatic, and coma). Note that use of an achromat would require modification of the coupler to accomodate an achromat's thickness.

Drawing number NVCS01 shows two possible lengths for the extension. Both lens elements described above use the longer extension. The shorter extension is for possible use with a shorter focal length lens.

The thread pitch on the Sony camcorder 52 mm objective filter mount is 0.75 millimeter (1.33 threads per millimeter). Our machine shop (may it now rest in peace) was not equipped with metric thread cutting equipment; hence the 40 TPI (threads per inch) specification on drawing number NVCS02. It would be better to use the correct metric equivalent even though the specified TPI does work.

The mechanical mount is sufficiently robust for careful hand held use without the aluminum base plate shown in drawing number NVCS05. However, we found it is more convenient and secure to use the optical coupler with a baseplate for lab bench tests and tripod use.

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APPENDIX B

Optical Coupler Engineering Drawings

Drawing Number NVCS01	Black Delrin Plastic Extension Tube
Drawing Number NVCS02	Aluminum Housing Tube, Camcorder Side
Drawing Number NVCS03	Aluminum Housing Tube, Extension Side
Drawing Number NVCS04	Assembly Detail
Drawing Number NVCS05	Aluminum Mounting Plate

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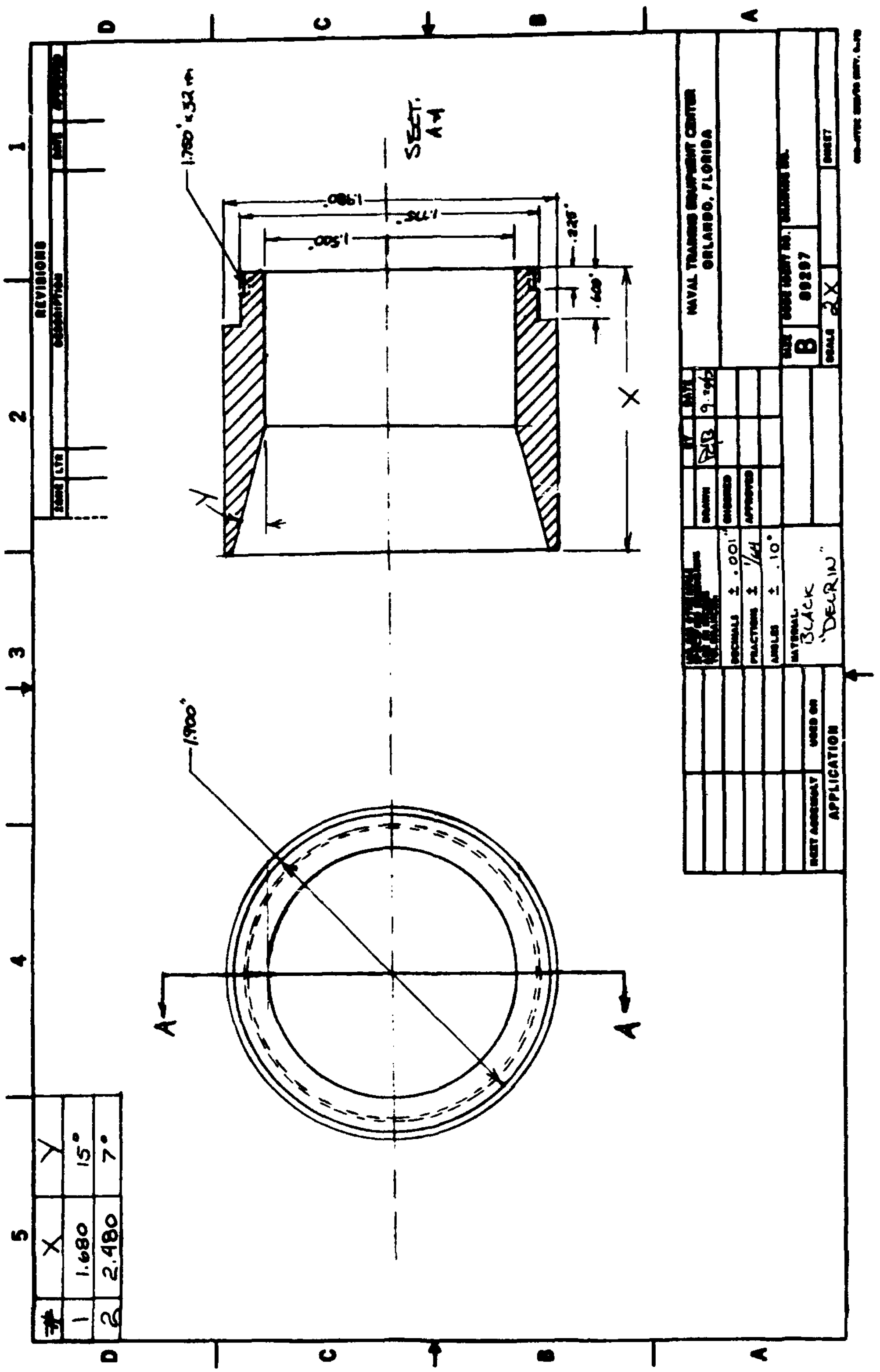

Drawing NVCS01
Black Delrin Plastic Extension Tube

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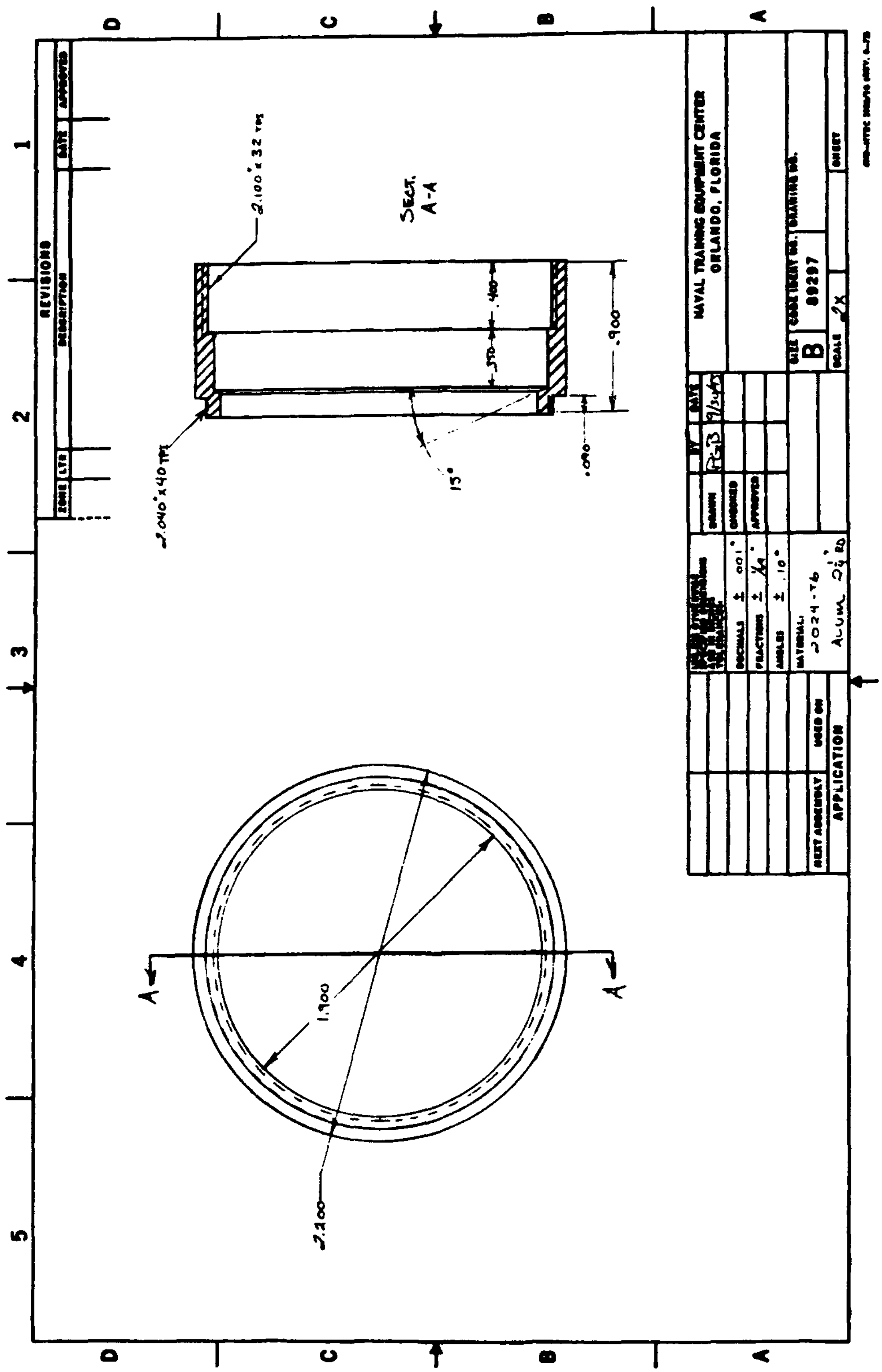

Drawing NVCS02
Aluminum Housing Tube, Camcorder Side

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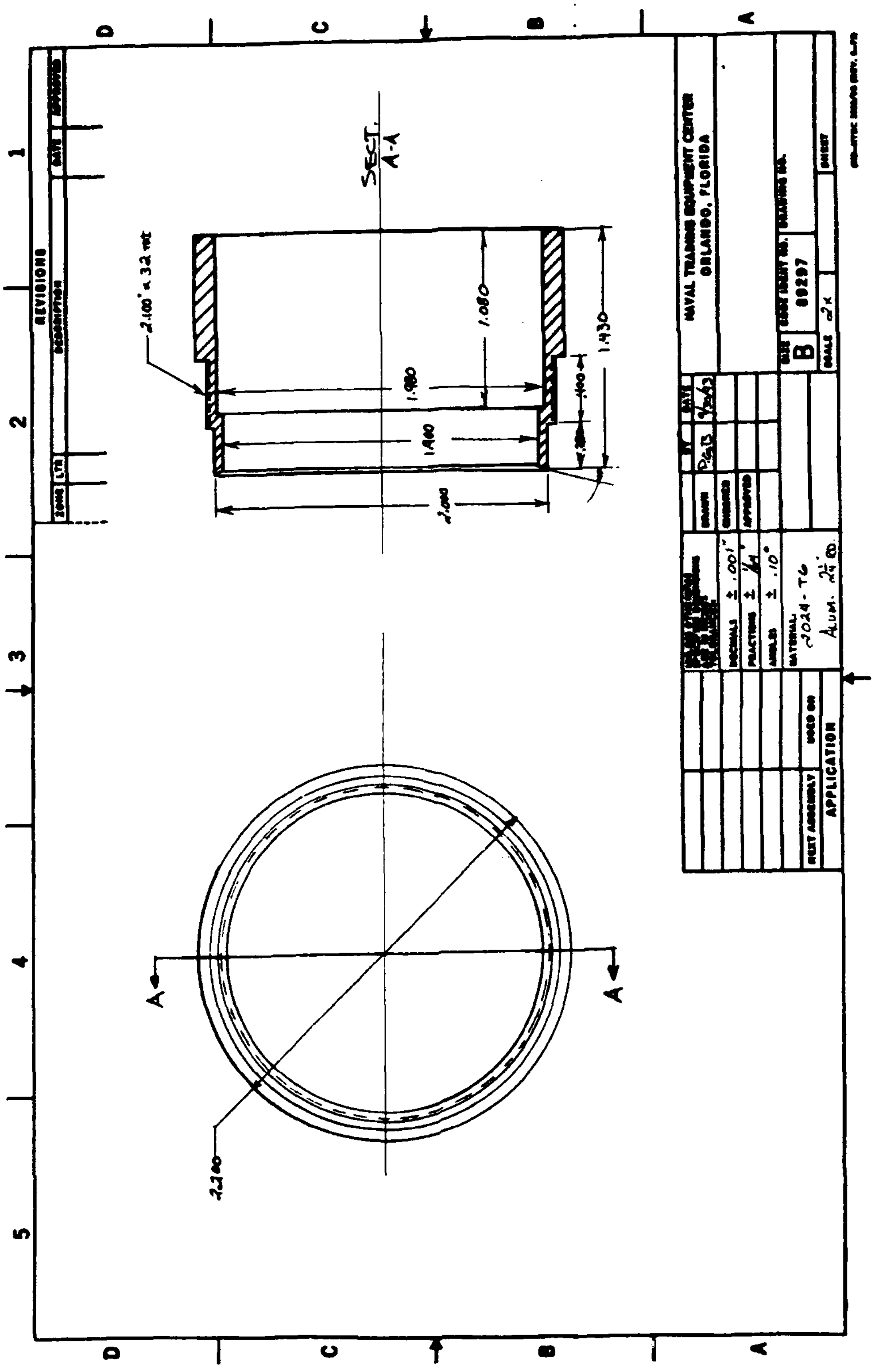

Drawing NVCS03
Aluminum Housing Tube, Extension Side

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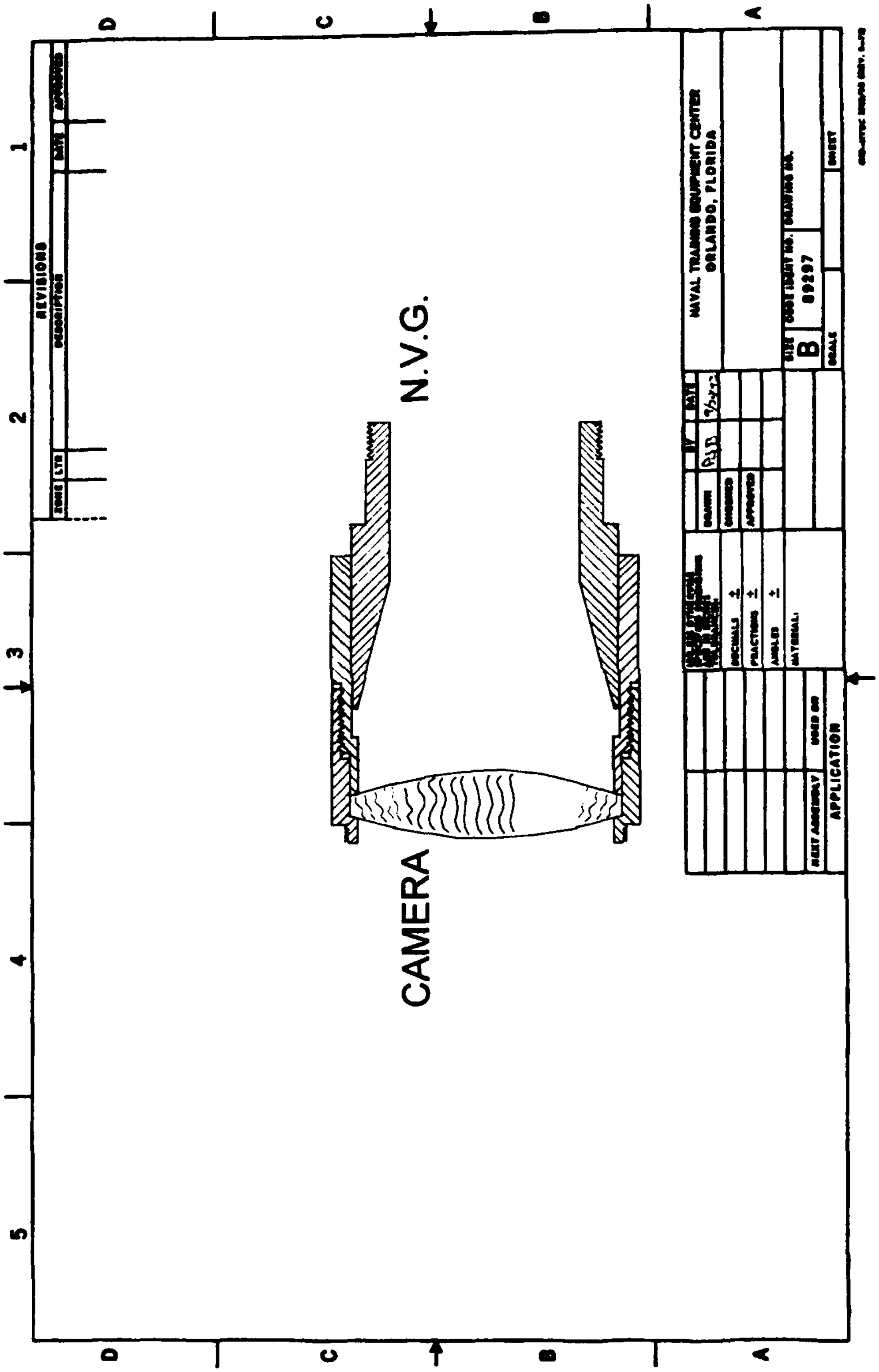

Drawing NVCS04
Assembly Detail

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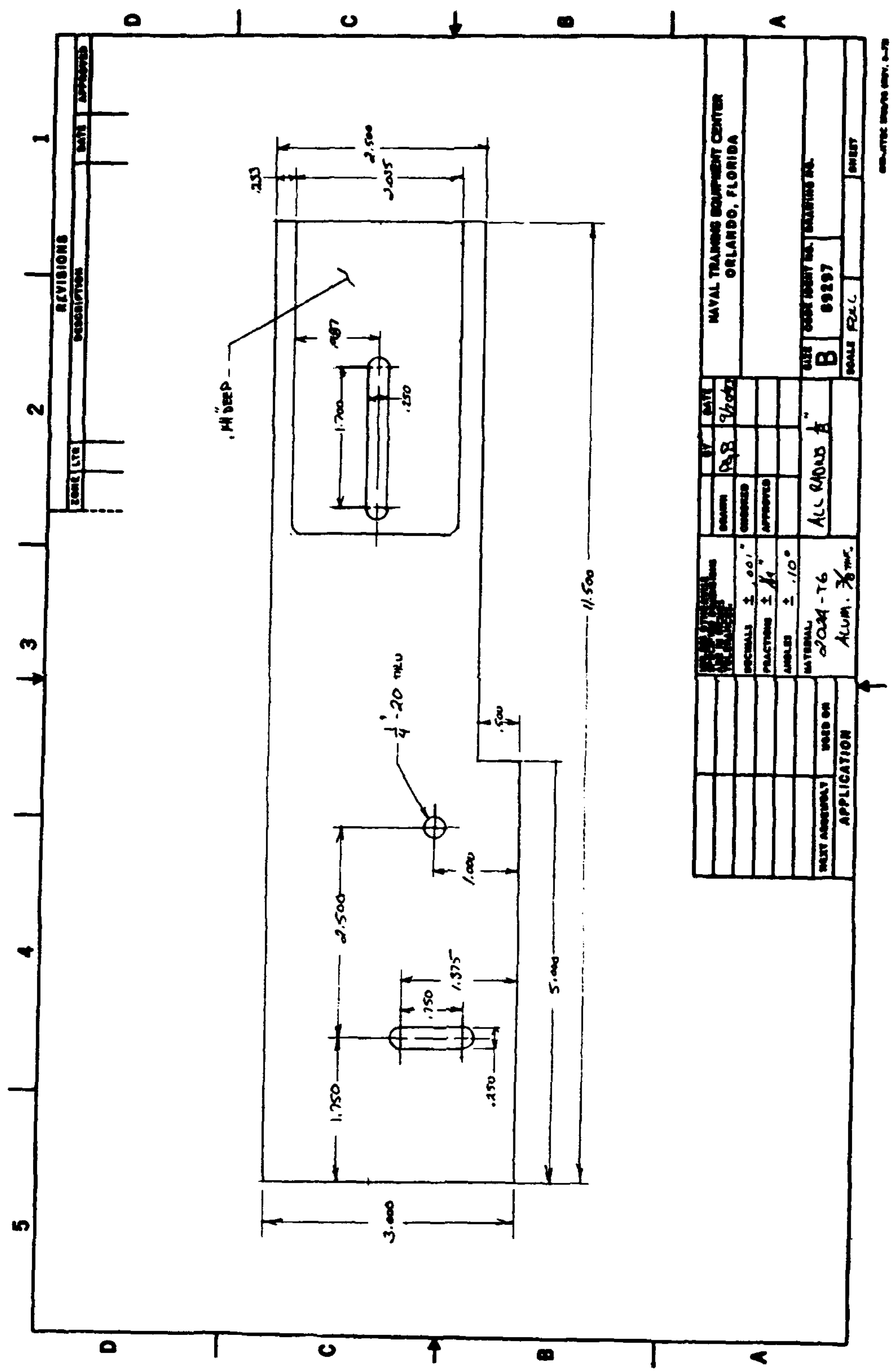

Drawing NVCS05
Aluminum Mounting Plate

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